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WALK ON FLOOR EYES CLOSED (WOFEC): A NEW ADDITION TO AN ATAXIA TEST BATTERY

Alfred R. Fregly, Ashton Graybiel, and Margaret J. Smith

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Alfred R. Fregly, Ashton Graybiel, and Margaret J. Smith

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13 ABSTRACT

The problem of quantifying a simple, often-used clinical ataxia test (tandem walking) for inclusion in an ataxia test battery was overcome by adopting the method of counting the number of heel-to-toe steps (1 to 10) a person can take without sidestepping with eyes closed and arms folded against chest. Standardization under these rigid conditions was based on testing 287 normal men and 100 normal women. Validation was based on testing 22 individuals having labyrinthine defects of varying severity and origin. This newly quantified test was found as valid an indicator of vestibular ataxia as other subtests of a multidimensional quantitative ataxia test battery with which it was compared. It has the advantages, however, because of its simplicity, that unlike all other items of the battery, 1) it appears to be free of age influences, at least within the age range of 17 to 65 years sampled; and 2) nearly all of the normal and none of the abnormal individuals obtained a perfect score. Its use in combination with a related subtest of the battery (Sharpened Romberg) having equally high validity (r pt. bis = .837) is recommended for rapid, economical screening purposes. Data analysis permitted an innovative definition of ataxia in terms of a 5th percentile cut-off criterion (4th percentile for WOFEC) relative to normative distributions of scores on all (five) ataxia battery subtests performed with eyes closed. A unique finding of special interest and having both practical and theoretical implications suggested that abnormal function of the semicircular canals alone or of the otolith organs alone may be sufficient to demonstrate vestibular ataxia with this test battery. An ataxia test battery that includes WOFEC has applications in general medical, aerospace medical, audiological, pharmacological, and psychological, otological, and neurological clinics and research laboratories.

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SUMMARY PAGE

THE PROBLEM

To quantify, standardize, and validate a simple "old" clinical ataxia test for inclusion in an ataxia test battery. Administered under rigid conditions, it consists of walking on the floor with eyes closed, arms folded against the chest, and feet in heel-to-toe (tandem) position.

FINDINGS

The test was quantified by adopting the method of counting the number of heel-to-toe steps (1 to 10) a person can take without sidestepping. Standardization was based on testing 287 normal men and 100 normal women. Validation was based on testing 22 individuals having labyrinthine defects of varying severity and origin.

This newly quantified test was found to be as valid an indicator of vestibular ataxia as other subtests of a multidimensional quantitative ataxia test battery with which it was compared. It has the advantages, however, because of its simplicity, that unlike all other items of the battery, 1) it appears to be free of age influences, at least within the age range of 17 to 65 years sampled; and 2) nearly all of the normal and none of the abnormal individuals obtained a perfect score. Its use in combination with a related subtest of the battery (Sharpened Romberg) having equally high validity (r pt. bis = .837) is recommended for rapid, economical screening purposes.

Data analysis permitted an innovative definition of ataxia in terms of a 5th percentile cut-off criterion (4th percentile for WOFEC) relative to normative distributions of scores on all (five) ataxia battery subtests performed with eyes closed.

A unique finding of special interest and having both practical and theoretical implications suggested that abnormal function of the semicircular canals alone or of the otolith organs alone may be sufficient to demonstrate vestibular ataxia with this test battery.

An ataxia test battery that includes WOFEC has applications in general medical, aerospace medical, audiological, pharmacological, and psychological, otological, and neurological clinics and research laboratories.

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INTRODUCTION

Testing a person's ability to walk tandemly on the floor with eyes closed has long been popular with otologists (3) and neurologists (2,28) as a qualitative ataxia test of vestibular, cerebellar, or other function. Standardization of the procedure for quantitative uses, however, appears to have been ignored.

The Walk On Floor Eyes Closed (WOFEC) test is the latest subtest to evolve in the development of new quantitative ataxia test batteries at this laboratory (4,6,15). Its development for quantitative use was motivated by the supposition that the simplest valid method of assessing vestibular function is by means of an ataxia test battery. Such a "natural" means of testing the integrity of the vestibular system has the great advantage of not disturbing the system and thereby not eliciting abnormal responses.

Walk A Line Eyes Closed (WALEC) was the antecedent of the WOFEC test. The test, which we have now abandoned, was conside d by us to be as much a test of spatial orientation as of ataxia (4,6,15).

The following is a report of normative standards of performance on this new test, indications of its validity, and implications for its general use in laboratories and clinics.

PROCEDURE

SUBJECTS

The normative sample of men included all men (N=287) who had undertaken the complete battery of ataxia tests, described below, since standardization of the WOFEC test. A wide age range (17 to 61 years) was represented in the sample; classification by type and occupation is shown in Table I. All had recently undergone a comprehensive medical evaluation and were considered to be in adequate, or better, health.

The normative sample of women (N=100), ages 18 to 65 years, also included a wide occupational range (Table I). All considered themselves to be in adequate, or better, health.

A sample of labyrinthine-defective men (N=22), in the age range of 20 to 54 years, constituted the test-validation group. Causes of the labyrinthine disturbances and the occupational status of these men are shown in Table I. All of these men had undergone a comprehensive medical, including audiological and vestibular, evaluation. Their general health ranged from good to excellent.

WOFEC TEST PROCEDURE

A WOFEC-test trial consisted of walking on the floor with eyes closed, arms folded against the chest, a maximum of ten heel-to-toe steps without sidestepping. On any trial the number of steps properly taken before sidestepping, stopping, opening the eyes,

Table I

Classification of Subjects by Type and Occupation

N	
	Normal Men
102	Student aviator volunteers for motion sickness research
87	Navy enlisted volunteer research subjects
29	Miscellaneous military and civilian scientific, medical, and technical staff members
23	NASA scientists and engineers
23	Army enlisted volunteers for high-impact acceleration research
11	College student research subjects
8	North American Rockwell research subjects
4	Navy deep-sea divers
287	
	Normal Women
55	Military and civilian scientific, technical, and clerical personnel
18	Naval Aerospace Medical Institute and Research Laboratory staff wives
14	Navy and civilian nurses
8	Red Cross volunteers - Pensacola Naval Hospital
5	Friends (housewives) of staff wives
100	
	Labyrinthine-Defective Men
17	Bilateral L-D's due to meningitis in early life (students or faculty at Gallaudet College, Washington, D. C.)
2	Bilateral L-D's having normal hearing (a sanitarian, and an aviator)
1	Bilateral L-D due to mastoiditis in early life (faculty member, Florida School for the Deaf and Blind, St. Augustine, Florida)
1	Otologist-referred as having "labyrinthitis" (an aviator)
1	Otologist-referred as having vestibular neuronitis (an aviator)
22	

or unfolding the arms was taken as the trial score. The scores obtained on the best three trials out of the maximum of five trials (minimum of three trials) administered were totalled and assigned as the test score. Maximum score obtainable was 30 (10 steps x 3 perfect trials). Subjects closed their eyes in the act of walking; that is, coincidental with tandem alignment of the lifted front foot with the still-standing rear foot. In other words, subjects were not permitted to close their eyes in a standing position and then to begin walking. Rather, tandem alignment and contact of the rear starting foot with the front starting foot in the process of walking with eyes closed was required as standard procedure and was counted as the first heel-to-toe step. All subjects were instructed to walk at a "normal speed" as illustrated by one or more demonstrations given by the examiner. Demonstration was necessary to prevent some individuals from walking "too slowly" and, therefore, performing the test as if it were a "standing-on-one-leg test" with each slow step. Similarly, individuals who walked "too quickly" were instructed to "slow down" on succeeding trials. These test procedures were very carefully adhered to, to maximize the objective, quantitative value of this relatively simple test.

TEST BATTERY

Each subject was administered the complete test battery (described in detail previously (6,15), with the exception of the WOFEC) in the following sequence:

1. Sharpened Romberg (SR): standing in strict tandem heel-to-toe position on the floor with eyes closed, arms folded against chest, and body erect for 60 seconds (Figures 1, and 2A).

2. Walk Eyes Open (Walk E/O): walking heel-to-toe with feet in strictly tandem position and arms folded against chest while in a body-erect position on a 3/4-inch-wide by 8-foot-long rail (Figures 1, and 3A,B).

3. Stand Eyes Open (Stand E/O): standing heel-to-toe with feet in a strictly tandem position and arms folded against the chest while in a body-erect position on the 3/4-inch-wide rail for a period of 60 seconds (Figures 1, and 3C).

4. Stand Eyes Closed (Stand E/C): standing, as for the Stand E/O test, on a 2-1/4-inch-wide by 30-inch-long rail for a period of 60 seconds (Figures 1, and 3D,E).

5. Stand One Leg Eyes Closed (SOLEC-R and SOLEC-L): standing stationary on the floor on each leg for 30 seconds while arms are folded against chest and body in erect position (Figure 2B,C).

6. WOFEC: walking on the floor eyes closed in the stringent position of arms folded against chest, body erect, and feet aligned tandemly heel-to-toe (Figures 1, and 2D).

All subjects were tested while wearing shoes on a hard floor without rugs. The men wore hard-soled shoes and the women wore hard-soled "flats."

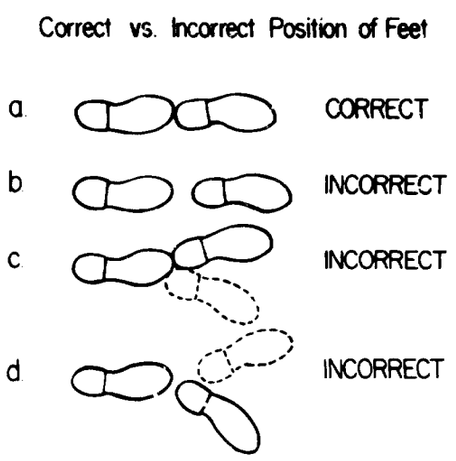

Figure 1

Correct vs incorrect positioning of the feet for all ataxia tests performed under tandem heel-to-toe conditions. (From ref. 10.)

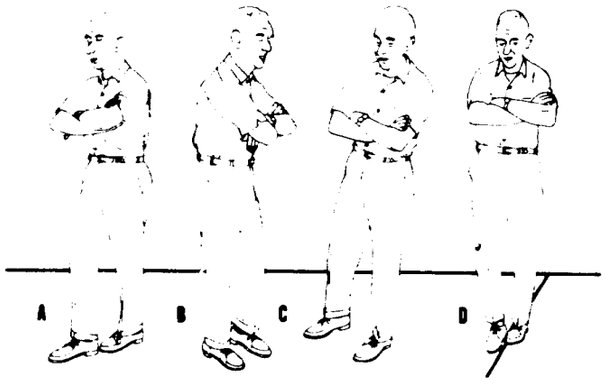

Figure 2

Correct (standardized) body and foot positions for testing on the "floor battery" of ataxia tests. A) Sharpened Romberg (SR); B) Stand One (Right) Leg Eyes Closed (SOLEC-R); (C) Stand One (Left) Leg Eyes Closed (SOLEC-L); D) Walk On Floor Eyes Closed (WOFEC).

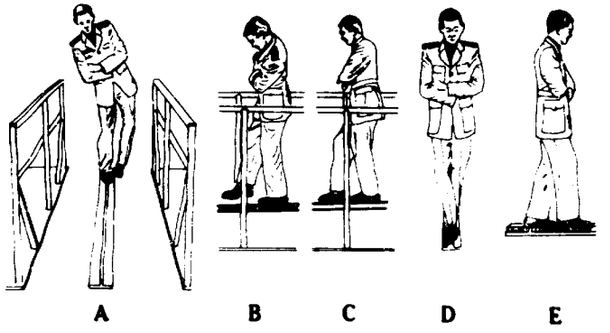

Figure 3

Standardized body and foot positions for testing on the "rail battery" of ataxia tests. A-B) Walking with eyes open on a 3/4-inch-wide, 8-foot-long rail (Walk E/O); C) Standing with eyes open on the 3/4-inch-wide-rail (Stand E/O); D-E) Standing with eyes closed on a 2-1/4-inch-wide, 30-inch-long rail (Stand E/C).

RESULTS AND DISCUSSION

The WOFEC scores, and their percentile equivalents, obtained by the normal men and women are presented in Table II. Although the women were significantly older (by 8.7 years) than the men ($P < .001$), the mean difference in WOFEC scores between those of the men (29.7) and those of the women (29.3) was not statistically significant. Moreover, the correlation of WOFEC scores with chronological age in either the male or the female sample was not statistically significant ($r = -.06$ and $-.05$, respectively). There was no significant sex influence on mean WOFEC scores, but a greater percentage of women than men (11 vs 4 percent, respectively) had imperfect scores. Because WOFEC scores are of diagnotic value only when they fall at the lower ends of the distributions, separate normative standards for men and women are included in Table II.

Table II

The WOFEC Test Scores of Normal Men and Women: Means, Standard Deviations, and Percentile Equivalents

N = 287 Normal Men Ages 17-61 Years (Mean Age = 24.5; S. D. = 8.73)		N - 100 Normal Women Ages 18-65 Years (Mean Age = 33.2; S. D. = 11.72)	
WOFEC Score	Percentile Equivalent	WOFEC Score	Percentile Equivalent
30	100th - 5th	30	100th - 12th
29	4th	29	11th
27-28	3rd	28	10th
23-26	2nd	27	9th
≤ 22	1st	26	8th
		24	6th
		23	5th
		22	3rd
		19-21	2nd
		≤ 18	1st
Mean: 29.7 S. D.: 1.65		Mean: 29.3 S. D.: 2.60	

The WOFEC test has high test-retest reliability (r = 1.00) as determined by re-testing 29 of the normal men on numerous (10 to 25) occasions over periods ranging from several weeks to several months.

A comparison of the normal men with the L-D men on the ataxia test battery* giving means, standard deviations, mean differences, and validity coefficients (r pt. bis) are shown in Table III; the tests are listed in validity rank order. The L-D men were not significantly different in age from the normal men. The mean differences and validity coefficients were significant ($P < .0005$) on all the tests of the battery. Of the subtests of the battery WOFEC had the highest validity, r = .838 (almost identical to the SR test's validity, r = .837). The first four tests constitute the "floor battery" while the last three tests constitute the "rail battery."

Table III

A Comparison of Scores of Normal Men With the L-D Men on the Ataxia Test Battery: Means, Standard Deviations, Mean Differences, and Validity Coefficients (r pt. bis)

Chron. Age and Ataxia Tests	Normal Men (N = 287)		L-D Men (N = 22)		Mean Differences	Validity Coefficients (r pt. bis)
	Mean	S. D.	Mean	S. D.		
Age	24.5	8.73	27.5	8.11	3.0	.089
WOFEC	29.7	1.65	14.1	7.82	15.6	.838
SR	224.8	35.65	19.3	14.13	205.5	.837
SOLEC-R	125.9	35.75	15.9	5.57	110.5	.647
SOLEC-L	126.2	35.03	14.2	5.85	112.0	.634
Walk E/O	12.6	2.48	7.0	2.51	5.6	.502
Stand E/C	88.8	55.08	9.2	3.21	79.6	.360
Stand E/O	35.3	29.64	8.6	2.17	26.7	.234

The WOFEC test has been shown to be a worthy addition to the quantitative ataxia test battery. Administered under rigid conditions, its discriminatory power appears to be as good as or better than any other single item of the battery. It fulfills the purpose of quantitatively differentiating between normal and labyrinthine-defective individuals and among the latter individuals. As a substitute for the qualitative method of testing tandem-walking ability, which has stood the test of time, the WOFEC test should prove to be far more useful clinically because it is simple, allows numerical scoring, and has good test-retest reliability.

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*A similar comparison between normal and L-D women was not done because of the limited number of normal women who had undertaken the entire test battery.

Unlike any other item of the ataxia test battery, the WOFEC has the advantage of being free of age and sex influences, at least within the age range of 17 to 65 years sampled. Its freedom from such influences is consistent with findings in a recent study of "floor battery" standardization (including WOFEC) on samples of younger (8 to 18 years old) individuals (1)*, and with findings reported previously on the predecessor of WOFEC, the WALEC test (6,15). The WOFEC's simplicity is further affirmed by its "all or none" quality--any initial test score that is less than perfect is regarded as being tentatively "abnormal" in terms of our criterion of abnormality discussed below. But inasmuch as perfect scores are so easily obtainable by the great majority of normal individuals, unlike all other items of the test battery it suffers the disadvantage of being incapable of differentiating among normal individuals. Moreover, the WOFEC test's simplicity may be overestimated during initial testing and give rise to a falsely abnormal score that conflicts with scores made on other ataxia test battery items. Although the test is a simple one, nevertheless its validity is dependent upon strict adherence to the rigid, standardized test procedures set forth. Thus, use of the WOFEC test alone as a definitive clinical or laboratory test of ataxia is not recommended even for screening purposes. Rather, it is recommended for such use only in combination with one or more other ataxia test battery items. The equally high discriminatory power of the WOFEC and SR tests, as shown in Table III, suggests that their combined use would offer an economical and valid means of assessing postural equilibrium for screening purposes. Their use in combination would constitute a short version of the "floor battery."

In our experience, the use of the "floor battery" alone appears sufficient for clinical, or even laboratory, purposes. It has proved consistently to be equal, or better, in sensitivity to the "rail battery" in the detection and charting of spontaneous and induced vestibular and related disturbances (4-21,27). In combination, however, the full test battery offers the advantages of greater sampling of multidimensional ataxia test behavior, greater opportunity to evaluate reliability and validity of results in a given individual, greater "top" in terms of test difficulty level and, hence, greater differentiation of individuals having superior body balance skills (4,6,15).

Because of the highly skewed distributions of scores on the items of the ataxia test battery, we have arbitrarily used (8) a 5th percentile cut-off criterion (4th percentile for WOFEC) +, rather than a standard score, for designating a score as being abnormal. However, an individual is considered by us to be frankly ataxic only when scores obtained on all tests performed with eyes closed (the "floor battery" plus the Stand E/C test

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*The designation, "National Aeronautics and Space Administration's floor ataxia test battery" in the title of this reference is misleading probably because the test battery was developed under NASA support (NASA Order Nos. R-47 and R-93).

+ In reference to normative standards for men (Table I), only a perfect score is a normal score on this test.

utilizing the 2-1/4-inch-wide rail) fall at or below the 5th percentile level. By this innovative definition, none of the men in normal group, with a single exception, and all of the L-D men were found to be ataxic. This one exception later manifested the unusual combination of normal canalicular function as shown by caloric tests (8,22) and loss of otolithic function (23) as determined by counterrolling responses (24,25). These findings were verified on a later re-evaluation. In this individual at least, abnormality of otolith function was sufficient to demonstrate vestibular ataxia. This is a finding of special interest in that it refutes previous conclusions that the vestibular ataxia observed during long-term follow-up evaluations of four streptomycin-treated Ménière's patients was ascribable mainly to loss of canal functions (17). This earlier finding reconsidered in the light of present findings suggests that normality of both the semicircular canals and the otolith organs may be necessary for the normal maintenance of postural equilibrium functions; abnormality of either vestibular organ alone may be sufficient for demonstrating vestibular ataxia.

Individuals with such discrete vestibular dysfunction--abnormal canals only or abnormal otolith organs only--would be ideal candidates for testing on a new, postural sway device of ingenious design considered suitable for diagnosing utricular otolith or semicircular canal deficiencies (26).

Other L-D men and women who had undertaken the entire test battery described herein and including the WALEC (4,6,8) would have scored below perfect on the WOFEC, without exception, had number of steps been counted during their futile attempts, despite frequent retesting, to complete the 12-foot distance required for quantitative scoring of their WALEC-test performances. On all items of the ataxia test battery performed with eyes closed their scores fell at or below the 1st percentile relative to normative standards (6,15). These L-D's included individuals treated with streptomycin sulfate for Ménière's disease (17), and unilateral L-D's who had compensated for surgical removal of an acoustic neuroma (4,6,8,27). In the latter group, scores obtained only on the walking and standing tests performed with eyes open were found to be superior to those test scores of all other L-D's who had been tested. Their scores were only slightly better on standing tests performed with eyes closed, but in terms of their ability to walk tandemly with eyes closed these unilateral L-D's scored no better than did the bilateral L-D's. This finding was considered indicative of the great sensitivity of the tandem walking test even to unilateral vestibular defects (4,8,27).

In the clinical application of the ataxia test battery maximum value is attainable, in our experience, with the method of "testing the limits." Limits-testing consists of retesting all individuals on those ataxia test items which produce scores falling within the range of the lowest 5 percent of the distributions of scores obtained on samples of normal individuals*. When low scores are obtained on tests performed initially with eyes closed, retesting with eyes open should immediately follow a rest period. Such procedure

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*The distributions of scores (for various age groupings) and their percentile equivalents based on testing large samples of normal individuals on the remaining items of the "floor battery" and on the three items of the "rail battery" appear elsewhere (6,15).

permits ruling out motor disability or other nonvestibular sources of poor perfomance. Following an additional rest period, the individual is retested with eyes closed. Continued poor performance upon retesting not only increases reliability and validity of results but also strengthens recommendations for more comprehensive clinical and/or laboratory evaluations of an individual's referral problem.

In addition to its value in the otology and neurology clinic, the WOFEC test used in combination with other items of the ataxia test battery would appear to be of value for assessing problems observed in general medical practice and, generally, for quantifying and documenting correlated information. Application of the test as a clinical and experimental tool in physiology and pharmacology and in general and aerospace medical, audiological, and psychological clinics and laboratories is recommended.

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